NON-CONDENSABLE GASES: TRACERS FOR RESERVOIR PROCESSES IN VAPOR-DOMINATED GEOTHERMAL SYSTEMS

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RESEARCH OBJECTIVES

At The Geysers field, 75 miles (120 km) north of San Francisco, California, the largest known vapor-dominated geothermal system in the world, injection of water back into the reservoir began with commercial exploitation in 1960. This injection, consisting of steam condensate and available surface water, was limited to 30% of the mass extracted. In late 1997, in the steam field operated by the Northern California Power Agency (NCPA), the amount of injection essentially doubled when lake water and treated waste water from the South East Geysers Effluent Pipeline were delivered to the southern part of the system.

The purpose of this work is to update studies of steam chemistry to reflect changes resulting from the increased liquid injection, to test the applicability of geochemical analysis to steam fields with a relative high rate of injection, and to evaluate the use of non-condensable gases to identify reservoir processes.

APPROACH

The methodology used in this study is different from that of earlier work, which was based on oxygen and hydrogen isotopes. This method is no longer effective because increased injection of creek and lake water and treated waste water has lessened the isotopic contrast between reservoir steam and injectate.

We use D'Amore's (1991) gas geothermometer grids and changes in total gas contents in the steam to construct time-series diagrams for individual NCPA wells over their entire production histories. Instead of describing the grid diagram behavior of each well, the behaviors are divided into types and interpreted according to their patterns. The distribution—over space and time—of non-condensable gases in the produced steam was also analyzed.

ACCOMPLISHMENTS

Grid diagrams for nearly 70 NCPA wells were drawn by a computer program using the equations given in D'Amore and Truesdell (1985). The wells have been in production from the mid-to-late-1980s to 2000 (later data were not available).

Four types of grid diagrams were recognized (linear, hairpin, cluster, and random) by Truesdell et al. (2001). In addition, contour figures showing the distribution of total non-condensable gas in the NCPA field were developed for different years (e.g., Figure 1).

The application of gas geochemistry to detect and monitor changes over time in steam temperatures and steam fractions (from individual wells) shows that steam from wells in the center of the NCPA field originates from fairly uniform conditions produced by injection. In contrast, steam from wells in peripheral areas originates from progressively drier reservoir zones, which may return to near-original conditions depending on the characteristics of the injection operations.

Contours of total non-condensable gases show that changes in the location and amount of liquid injected have been very effective in limiting gas concentrations in the steam produced by most of the NCPA wells.

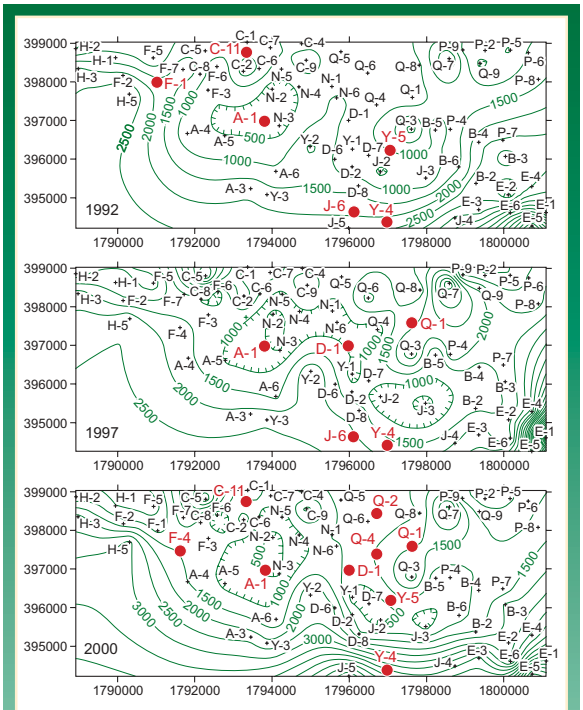

Figure 1. NCPA Geysers steam field. Contours of total non-condensable gas in the produced steam (in ppmv) for 1992, 1997, and 2000. Injection wells in use are shown as solid circles.

SIGNIFICANCE OF FINDINGS

This study confirms the usefulness of non-condensable gases to identify reservoir processes in vapor-dominated geothermal systems, particularly in The Geysers field. Variations of gas ratios in the produced steam explain processes resulting from large-scale production and from an increasing amount of injected liquid. It also illustrates that changes in the source (i.e., chemical characteristics) of the injectate are useful in detecting the various phenomena occurring in the reservoir.

RELATED PUBLICATIONS

D'Amore, F., and A.H. Truesdell, Calculation of geothermal reservoir temperatures and steam fraction from gas compositions, Geothermal Resources Council Transactions 9(I), pp. 305–310, 1985.

D'Amore, F., 1991, Gas geochemistry as a link between geothermal exploration and exploitation, in Application of Geochemistry in Geothermal Reservoir Development, edited by F.D'Amore, UNITAR/UNDP, Rome, pp. 93–117, 1991.

Truesdell, A., B. Smith, S. Enedy, and M. Lippmann, Recent geochemical tracing of injection-related reservoir processes in the NCPA Geysers field, Geothermal Resources Council Transactions 25, 2001.

ACKNOWLEDGMENTS

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